A TWO COMPONENT MODEL FOR THERMAL EMISSION FROM ORGANIC GRAINS IN COMET HALLEY

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Observations of Comet Halley in the near infrared reveal a triple-peaked emission feature near $3.4\mu m$, characteristic of C-H stretching in hydrocarbons (e.g., Wickramasinghe and Allen, 1986). A variety of plausible cometary materials exhibit these features, including the organic residue of irradiated candidate cometary ices (such as the residue of irradiated methane ice clathrate [Khare *et al.*, 1988]), and polycyclic aromatic hydrocarbons (Allamandola *et al.*, 1987). Indeed, *any* molecule containing $-CH_3$ and $-CH_2-$ alkanes will emit at $3.4\mu m$ under suitable conditions. Therefore tentative identifications must rest on additional evidence, including a plausible account of the origins of the organic material, a plausible model for the infrared emission of this material, and a demonstration that this conjunction of material and model not only matches the $3-4\mu m$ spectrum, but also does not yield additional emission features where none is observed. In the case of the residue of irradiated low-occupancy methane ice clathrate, we argue that the laboratory synthesis of the organic residue well simulates the radiation processing experienced by Comet Halley (We summarize the variety of post-accretion radiation environments experienced by the comet in Table 1; ultraviolet and charged particle irradiation of dust grains prior to cometary aggregation will also be of importance [Greenberg and Grim, 1986]). We use a simple two-component model for emission from dust in the Halley coma to predict an observed flux (heliocentric distance 1.16 AU, geocentric distance 0.549 AU) given by $F_\lambda = C_\lambda + \Omega\tau'_\lambda B_\lambda(T = 600K) + \Omega\tau B_\lambda(T = 350K)$, where C_λ is the scattered solar flux, Ω is the telescope solid angle, τ is the optical depth of the blackbody continuum emitters (T=350 K), $\tau'_\lambda = \alpha(a/\lambda)ln(t_\lambda^{-1})$ is the optical depth of the submicron (radius a~ $0.1\mu m$) organic emitters (T=600 K), and t_λ is given by the laboratory transmission spectrum of the residue of irradiated CH_4 ice clathrate (Fig. 1, after Khare *et al.*, 1988). We show that this model fits the $3.4\mu m$ feature (Fig. 2), provides optical depths in excellent agreement with those determined by spacecraft, and accounts for the absence of features at longer wavelengths (Figs. 3 & 4), despite the presence of such features in transmision spectra of typical laboratory-produced organics (e.g., as seen in Fig. 1).

REFERENCES

Allamandola, L.J., Tielens, A.G.G.M, and Barker, J.R. (1987). *Polycyclic Aromatic Hydrocarbons and Astrophysics* (eds. A. Léger *et al.*), 255-271 (D. Reidel).
Greenberg, J.M., and Grim, R. (1986). *20th Eslab Symposium on the Exploration of Halley's Comet* **2**, 255-263.
Khare, B.N., Thompson, W.R., Murray, B.G.J.P.T., Chyba, C.F., Sagan, C., and Arakawa, E.T. (1988). *Icarus, in press*.
Wickramasinghe, D.T., and Allen, D.A. (1986). *Nature* **323**, 44-46.

TABLE 1. COMET HALLEY IRRADIATION HISTORY

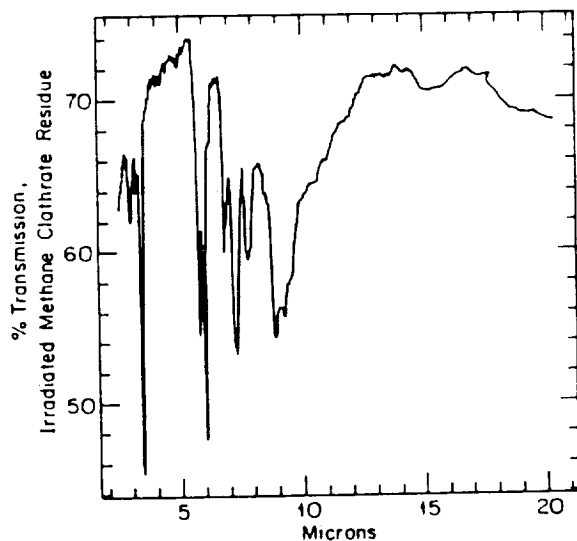| ENVIRONMENT	DOSE (KeV/cm^3)	DEPTH	REMARKS
INNER SOLAR SYSTEM Solar Wind, 1 Orbit	10^{20}	~0.1 μm	Comet Shielded Within ~ 5 AU
Solar Wind, 10^2-10^3 Orbits	10^{22} - 10^{23}	~0.1 μm	
OORT CLOUD Solar Wind, 4.6 Gyr	10^{21}	~0.1 μm	
Cosmic Rays, 4.6 Gyr	10^{21} 10^{20}	~1 m ~10 m	
Radionuclides, 4.6 Gyr	10^{20}	Entire Comet	Assumes No Differentiation ^{26}Al ~ 80%
INNER OORT CLOUD Solar Wind, ~1 Gyr	10^{26}	~1 μm	Erosion ?

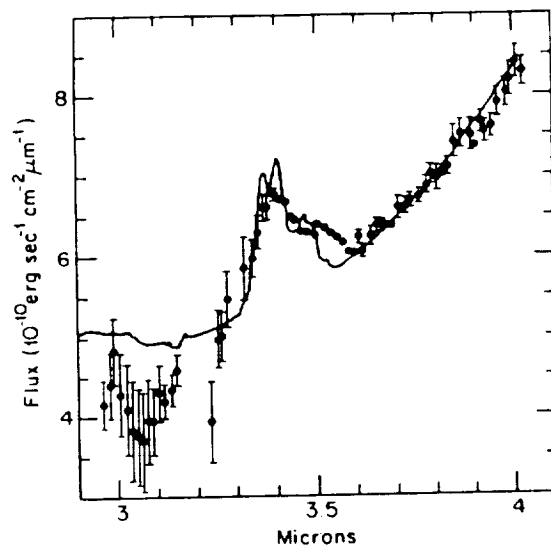Fig. 1. Transmission spectrum of irradiated CH$_4$ clathrate residue (after Khare et al., Icarus, to be published [1987]).

Fig. 2. Best fit (solid curve) to 3-4μm spectrum of Comet Halley observed by Wickramasinghe & Allen (Nature 323, 44-46 [1986]). The absorption feature at ~ 3.1μm, probably O-H stretch, is not modeled.
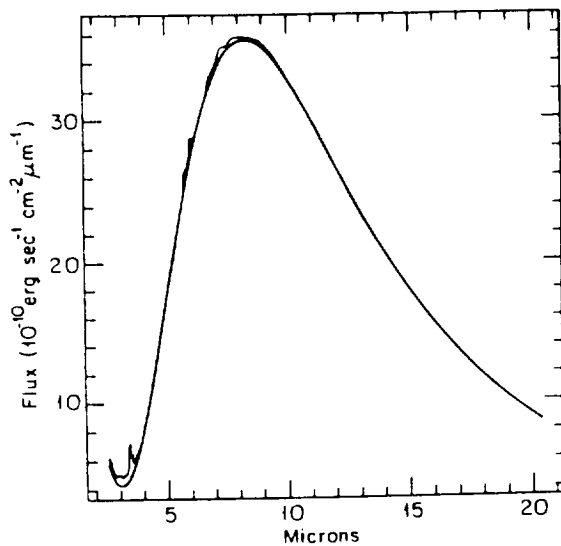

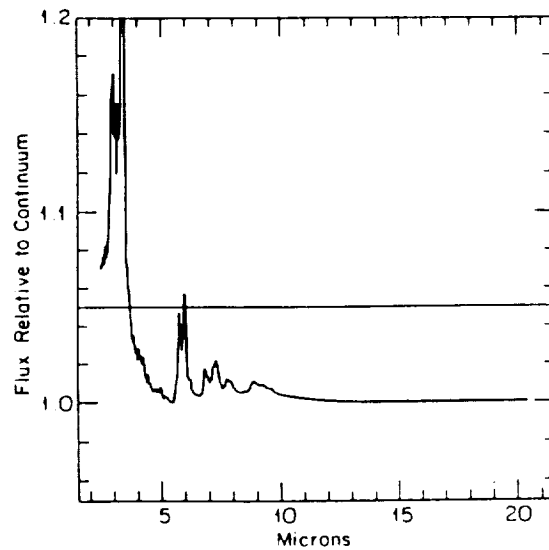Fig. 3. The Comet Halley 2-20μm spectrum predicted by our model, compared to that of a 350 K blackbody.

Fig. 4. The predicted 2-20μm spectrum, after dividing out the continuum. Only the 3.4μm feature rises above the 5%-above-continuum level (indicated by the solid line).